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EVALUATION OF MOTOR GASOLINE IN THE JET FUEL THERMAL OXIDATION --ETC(U)

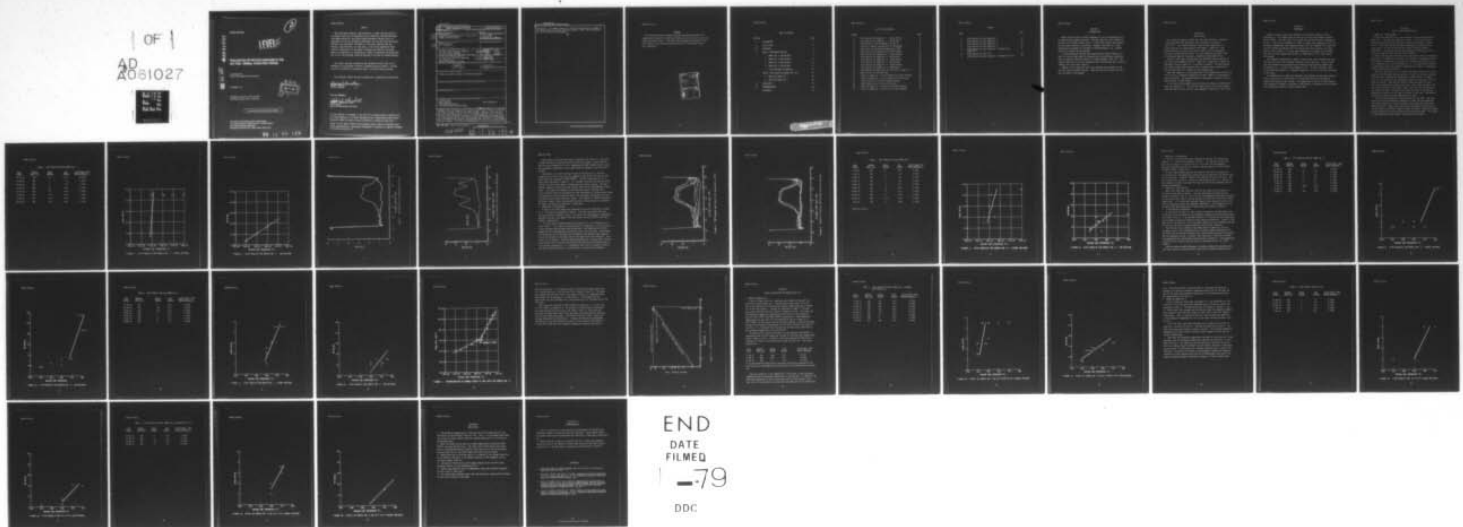
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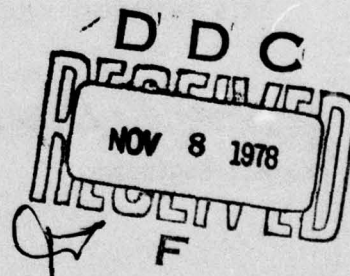
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EVALUATION OF MOTOR GASOLINE IN THE JET FUEL THERMAL OXIDATION TESTER

*FUELS BRANCH
FUELS AND LUBRICATION DIVISION*

OCTOBER 1978

TECHNICAL REPORT AFAPL-TR-78-86
Final Report, January 1976 - July 1978



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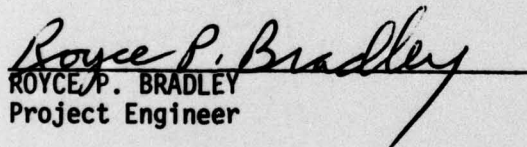
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This technical report has been reviewed and is approved for publication.


ROYCE P. BRADLEY
Project Engineer

FOR THE COMMANDER


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INVESTIGATED. THE THERMAL STABILITY OF THE RESULTING BLEND MAY BE LOWERED TO THE THERMAL STABILITY LEVEL OF THE MOTOR GASOLINE. HENCE, THE BLEND MAY NOT MEET JP-4 SPECIFICATION REQUIREMENTS.



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FOREWORD

This technical report presents and discusses data generated in an experimental program to evaluate four motor gasoline fuels in the Jet Fuel Thermal Oxidation Tester. The report was prepared by personnel of the Fuels Branch, Fuels and Lubrication Division, Air Force Aero Propulsion Laboratory.

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SECTION I INTRODUCTION

Motor gasoline (gas) has been suggested for use as an emergency fuel in turbine engine powered aircraft. The fuel would be used to enable an aircraft to fly from a remote area to a field where turbine fuel meeting military specifications is available. However, the effect of a high temperature environment on the deposit forming tendency (i.e., thermal stability) of motor gas was unknown.

A second potential problem area concerning the thermal stability of motor gas occurs when pipe-line companies use the multiproduct approach. That is, when more than one product is pumped through a pipe line. The thermal stability of JP-4 has reportedly been affected when gas is used to separate JP-4 from other products.

Samples of four motor gas fuels were obtained and evaluated in the Jet Fuel Thermal Oxidation Tester. Blends of two of the fuels with JP-4 were included in the program.

SECTION II FUELS TESTED

Four different samples of motor gas fuel were evaluated. Sample Nr. 1 contained sufficient tetraethyl lead to produce an antiknock index of 95. This sample had been stored at room temperature in a closed container for approximately three months. Sample Nr. 2 was obtained directly from the tank used to supply fuel for government vehicles at Wright-Patterson AFB. The fuel contained tetraethyl lead in sufficient quantity to produce a combined octane number of 89.

Samples 3 and 4 were low-lead motor gas obtained from two batches of fuel used for government vehicles. Sample Nr. 3 contained 0.7 gm/gal of tetraethyl lead and sample Nr. 4 contained 0.6 gm/gal. The lead content was slightly higher than expected and is probably due to evaporation of the gas resulting in an increase in lead concentration.

Motor gas sample Nr. 3 was blended with a JP-4 identified as AFFB-16-73. This JP-4 has a breakpoint temperature of 249°C (480°F) as determined by previous testing. The minimum breakpoint temperature allowed by the JP-4 specification is 260°C (500°F).

A JP-4 with a high thermal stability level was chosen for blending with motor gas sample Nr. 4. The JP-4 was identified as 77-6 and the thermal stability data for this fuel will be presented in Section V of this report.

SECTION III PROCEDURES

Thermal oxidation tests were conducted using ASTM Test Method D 3241-77 (Reference 1). This method requires the use of the Jet Fuel Thermal Oxidation Tester (JFTOT). The fuels were first tested near the specification temperature for JP-4. The test was repeated at a lower or higher tube temperature until the breakpoint temperatures were determined based on Visual (Appendix B of Specification MIL-T-5624K) and Mark 8A TDR tube ratings and, where possible, on filter pressure drop increase. All tests were conducted at a pressure of 3.43 MN/M^2 (500 psig) and the samples were stored at a temperature of 2°C (36°F) during the program.

The breakpoint temperatures, based on tube ratings, were determined by plotting the data points and free-hand fitting a line to the data. Visual ratings that were between two Code numbers were plotted as being halfway between the two numbers; e.g., a Code 4+ was plotted as a 4.5. In those instances, where a tube contained "peacock" or "abnormal" deposits, a P or an A has been indicated on the plots.

The temperatures at which the free-hand lines through the data pass through a Visual rating of 3 or a TDR rating of 12 have been taken as the breakpoint temperatures based on tube ratings. The temperature at which a filter pressure drop increase of 25mm-Hg is attained in 150 minutes is considered to be the breakpoint temperature based on filter pressure drop.

SECTION IV RESULTS USING MOTOR GASOLINE

1. SAMPLE NR. 1 TUBE RATINGS

A total of eight JFTOT tests were conducted on the fuel identified as Sample Nr. 1. The data are tabulated in Table 1. The Visual and TDR ratings obtained during each test were plotted and are shown in Figures 1 and 2. The Visual and TDR breakpoint temperatures obtained from the lines drawn in the two figures are 250°C (482°F) and 252°C (486°F), respectively. The current specification breakpoint temperature for JP-4 type fuels based on Visual ratings is 260°C (500°F).

Peacock type deposits were obtained at temperatures above the breakpoint temperature. The appearance of peacock type deposits at temperatures above the breakpoint temperature of the fuel is in agreement with results previously obtained on jet fuels (Reference Nr. 2). The tube deposits obtained at temperatures below the breakpoint temperature are similar in appearance to those obtained from jet fuels.

The TDR is connected to a X-Y plotter that permits the plotting of the output of the TDR versus the tube position. A plot for the test conducted on 29 Jan 76 at a maximum tube temperature of 260°C (500°F) is shown in Figure 3. The lower curve was obtained by running the new tube in the TDR prior to the test. Note that the pretest ratings are almost entirely below zero throughout the length of the tube. This simply indicates that the light reflectance of the tube is higher than the light reflectance of the calibration tube. The upper curve shows the effect of the deposits formed during the test on the light reflectance of the tube. The shape of the curve is similar to those obtained for jet fuels.

X-Y plots were obtained for the TDR ratings for all tests. The plots resulting for tests conducted at temperatures lower than the temperature resulting in the plot in Figure 3 produce similar type curves but have a lesser magnitude. However, when the peacock type deposits became evident the curve took on a different shape as shown in Figure 4. Note that instead of one large peak in the curve there are now three small peaks. This change in shape often occurs when peacock type deposits are evident.

TABLE 1. JFTOT RESULTS FOR FUEL SAMPLE NR. 1

<u>DATE TESTED</u>	<u>CONTROL TEMP. (°C)</u>	<u>VISUAL RATING</u>	<u>TDR RATING</u>	<u>FILTER PRESS. DROP MM-HG (MINUTES)</u>
16 Jan 76	260	4+	16.5	25 (122)
19 Jan 76	240	1	3.0	0 (150)
20 Jan 76	250	1	11.3	0 (150)
21 Jan 76	260	4+	14.0	0 (150)
29 Jan 76	260	4+	18.0	0 (150)
3 Feb 76	270	4+ P	21.0	1 (150)
25 Feb 76	250	4+ P	16.0	0 (150)
26 Feb 76	280	4+ P	46.0	0 (150)

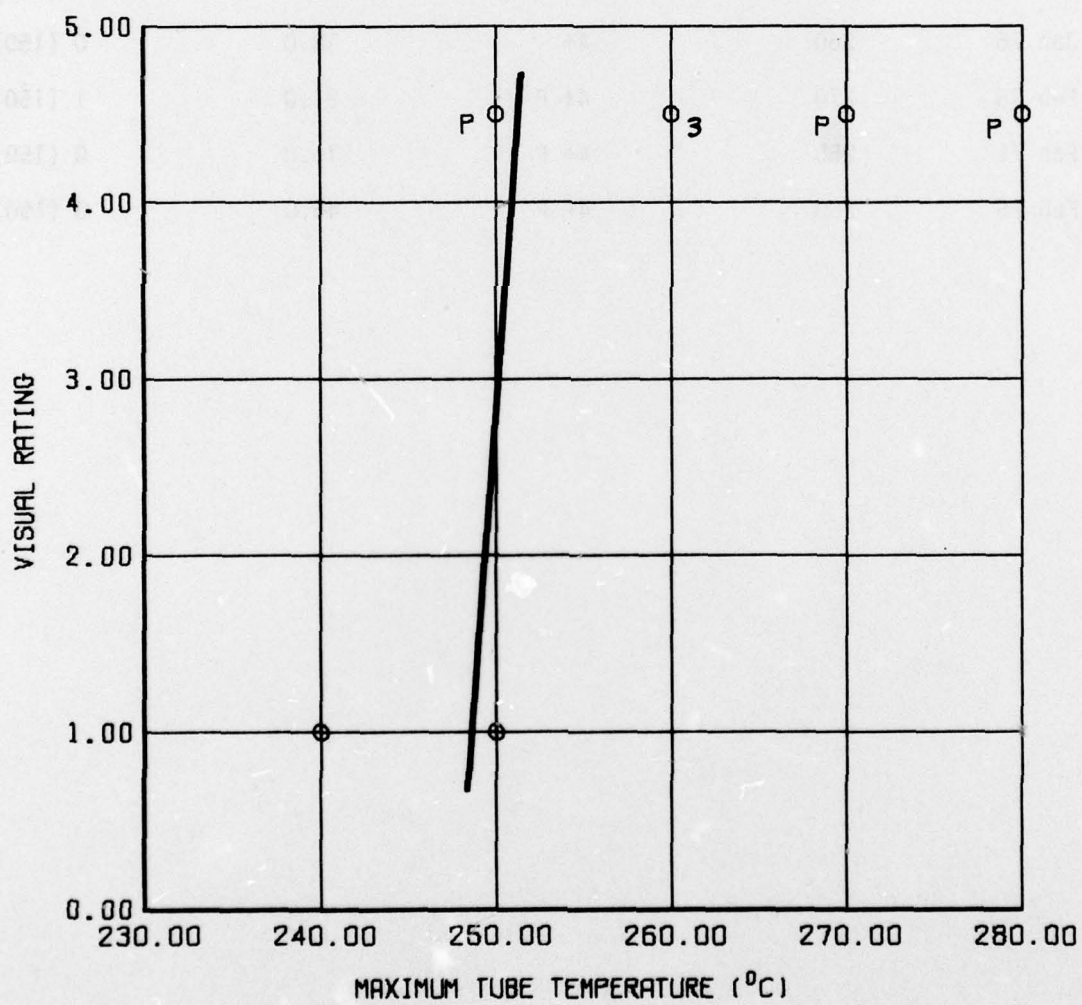


FIGURE 1. JFTOT RESULTS FOR SAMPLE NR. 1 - VISUAL RATINGS

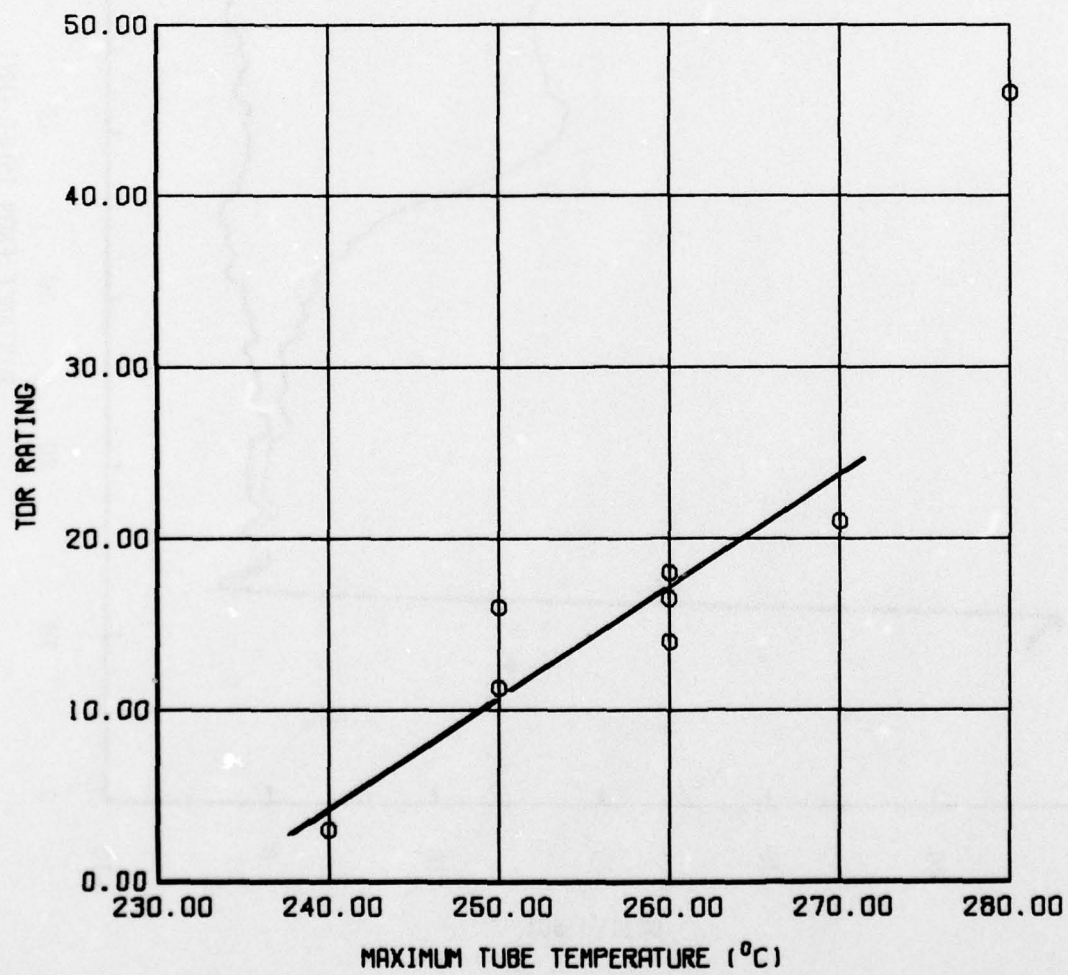


FIGURE 2. JFTOT RESULTS FOR SAMPLE NR. 1 - TOR RATINGS

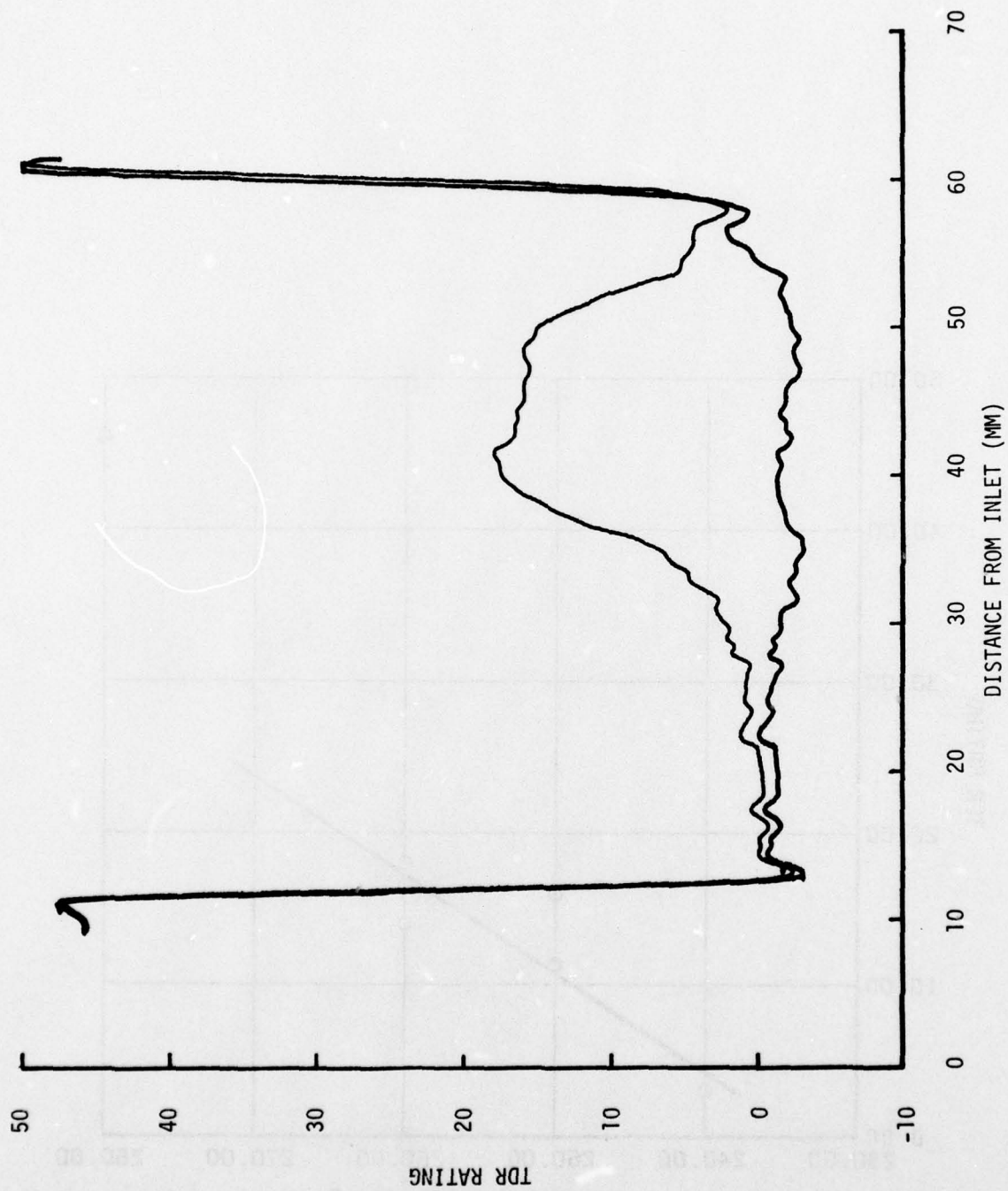


Figure 3. TDR Ratings for Test Conducted on 29 Jan 76

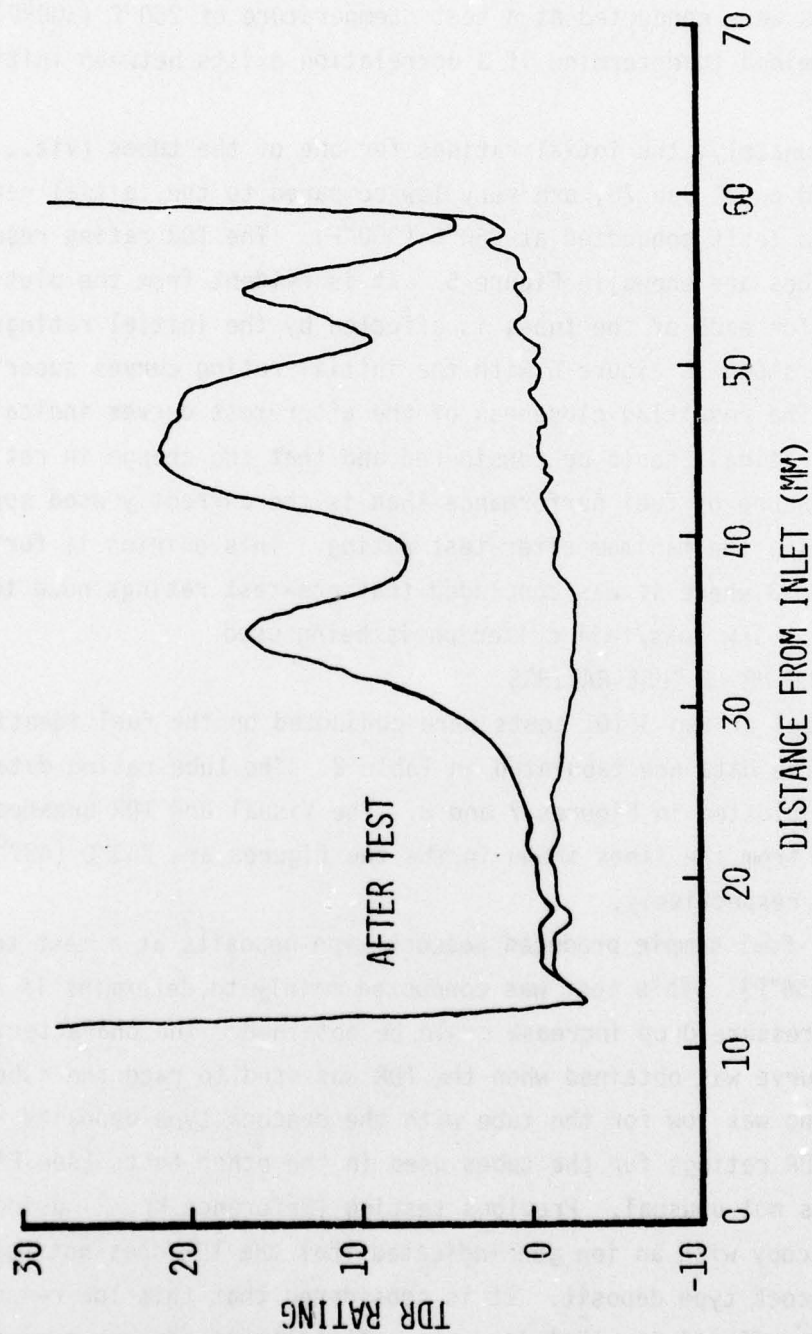


FIGURE 4. EFFECTS OF PEACOCK TYPE DEPOSITS ON TDR RATINGS

Some concern exists that the initial ratings of the tubes (i.e., pre-test ratings) may have a significant effect on the test results. Since three of the tests were conducted at a test temperature of 260°C (500°F) the X-Y plots were examined to determine if a correlation exists between initial and final ratings.

Fortunately, the initial ratings for one of the tubes (viz., the test conducted on 21 Jan 76) are very low compared to the initial ratings for the other two tests conducted at 260°C (500°F). The TDR rating results for all three tubes are shown in Figure 5. It is evident from the plot that the final ratings for each of the tubes is affected by the initial ratings. The same data are shown in Figure 6 with the initial rating curves superimposed on each other. The resulting closeness of the after-test curves indicates that initial ratings should be considered and that the change in ratings may be a more valid measure of fuel performance than is the currently used approach of only considering the maximum after-test rating. This opinion is further supported in Reference 3 where it was concluded that pre-test ratings need to be accounted for when a low pass/fail criterion is being used.

2. SAMPLE NR. 2 TUBE RATINGS

A total of ten JFTOT tests were conducted on the fuel identified as Sample Nr. 2. The data are tabulated in Table 2. The tube rating data from each test are plotted in Figures 7 and 8. The Visual and TDR breakpoint temperatures obtained from the lines shown in the two figures are 253°C (487°F) and 250°C (482°F), respectively.

This fuel sample produced peacock type deposits at a test temperature of 280°C (536°F). This test was conducted mainly to determine if a failure due to filter pressure drop increase could be obtained. The characteristic multi-peaked curve was obtained when the TDR was used to rate the tube. The maximum TDR rating was low for the tube with the peacock type deposits when compared to the TDR ratings for the tubes used in the other tests (see Figure 8). This result is not unusual. Previous testing (Reference Nr. 2) using Auger Electron Spectroscopy with an ion gun indicated that the TDR does not respond properly to a peacock type deposit. It is considered that this low response is due to the high reflectivity that is a characteristic of peacock type deposits.

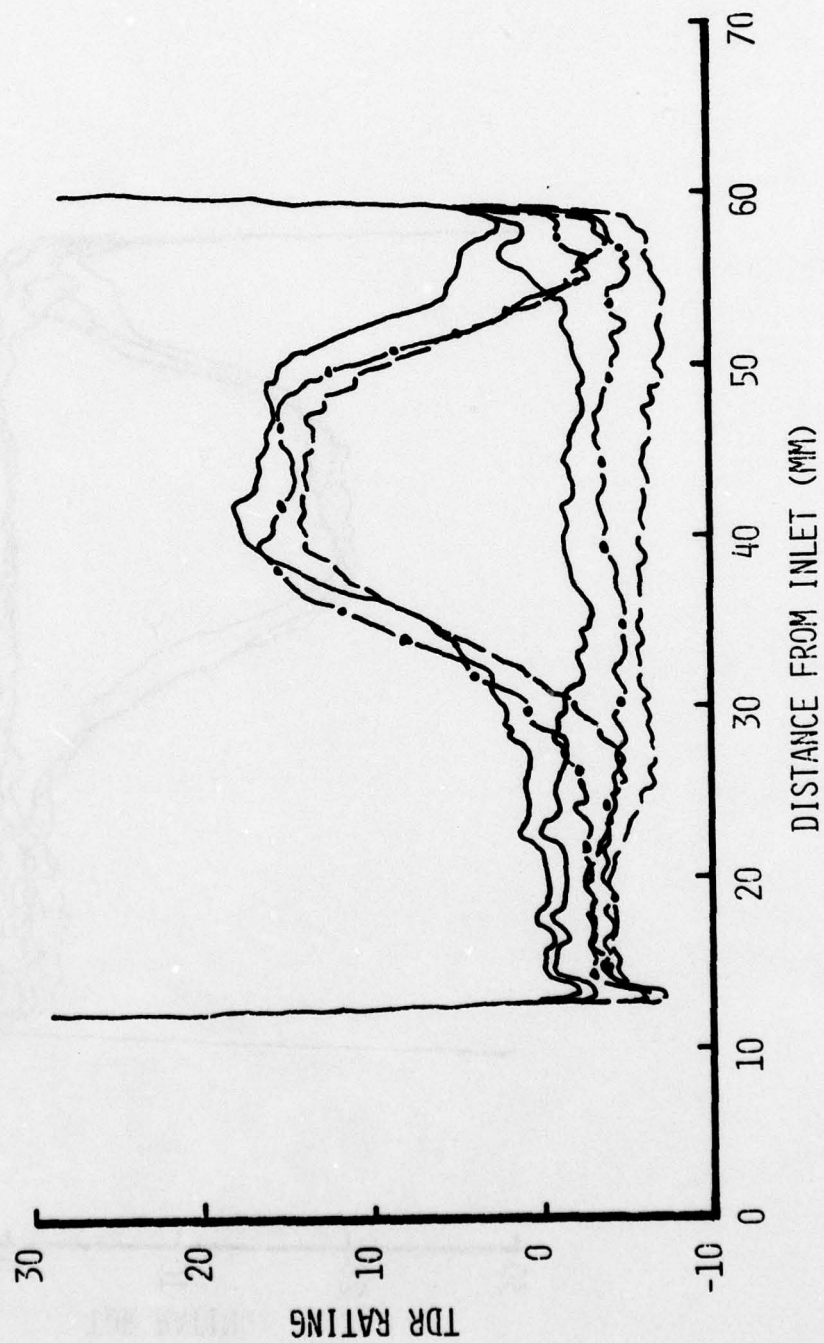


FIGURE 5. TDR RATINGS FOR THREE TESTS CONDUCTED AT 260°C

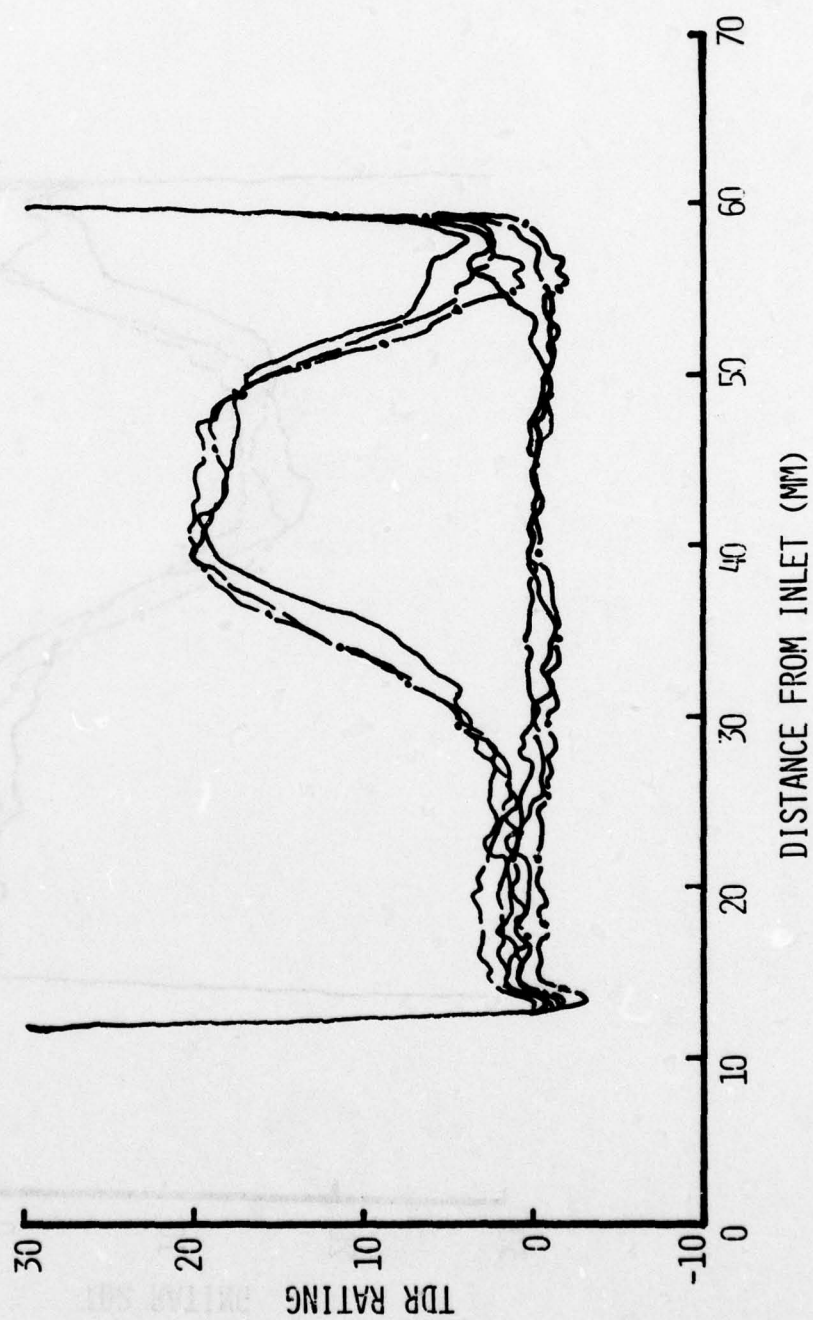


FIGURE 6. EFFECT OF INITIAL TDR RATINGS ON FINAL RATINGS

TABLE 2. JFTOT RESULTS FOR FUEL SAMPLE NR. 2

<u>DATE TESTED</u>	<u>CONTROL TEMP. (°C)</u>	<u>VISUAL RATING</u>	<u>TDR RATING</u>	<u>FILTER PRESS. DROP MM-HG (MINUTES)</u>
1 Mar 76	250	3	19.0	0 (150)
2 Mar 76	245	2	6.5	0 (150)
12 Mar 76	245	1+	9.0	0 (150)
12 Mar 76	255	2	6.3	0 (150)
17 Mar 76	260	3	17.0	0 (150)
19 Mar 76	250	1+	12.0	0 (150)
29 Mar 76	257	4+	15.5	0 (150)
29 Mar 76	252	4	15.0	0 (150)
30 Mar 76	280	4+ P	21.0*	0 (150)
5 Apr 76	253	3	15.0*	0 (150)

*Rated on 4 May 76

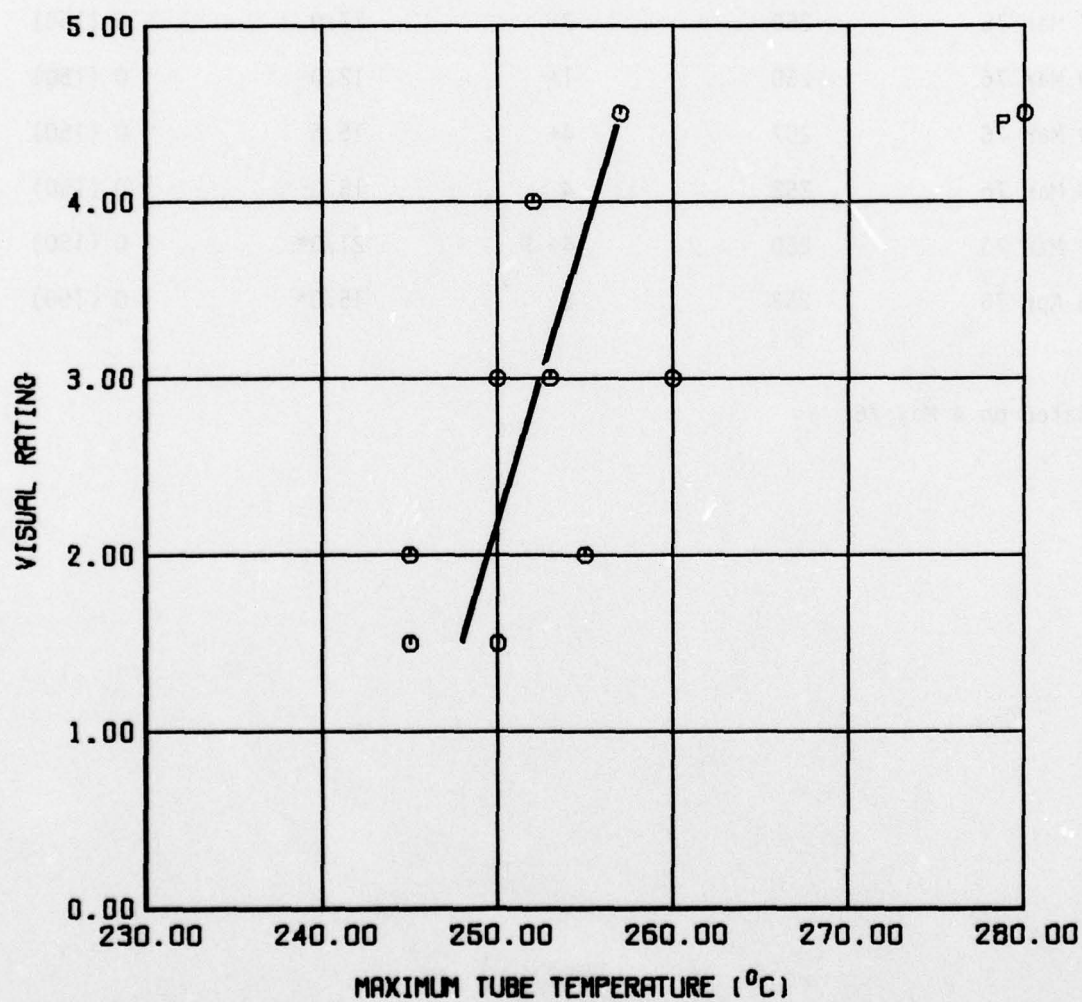


FIGURE 7. JFTOT RESULTS FOR SAMPLE NR. 2 - VISUAL RATINGS

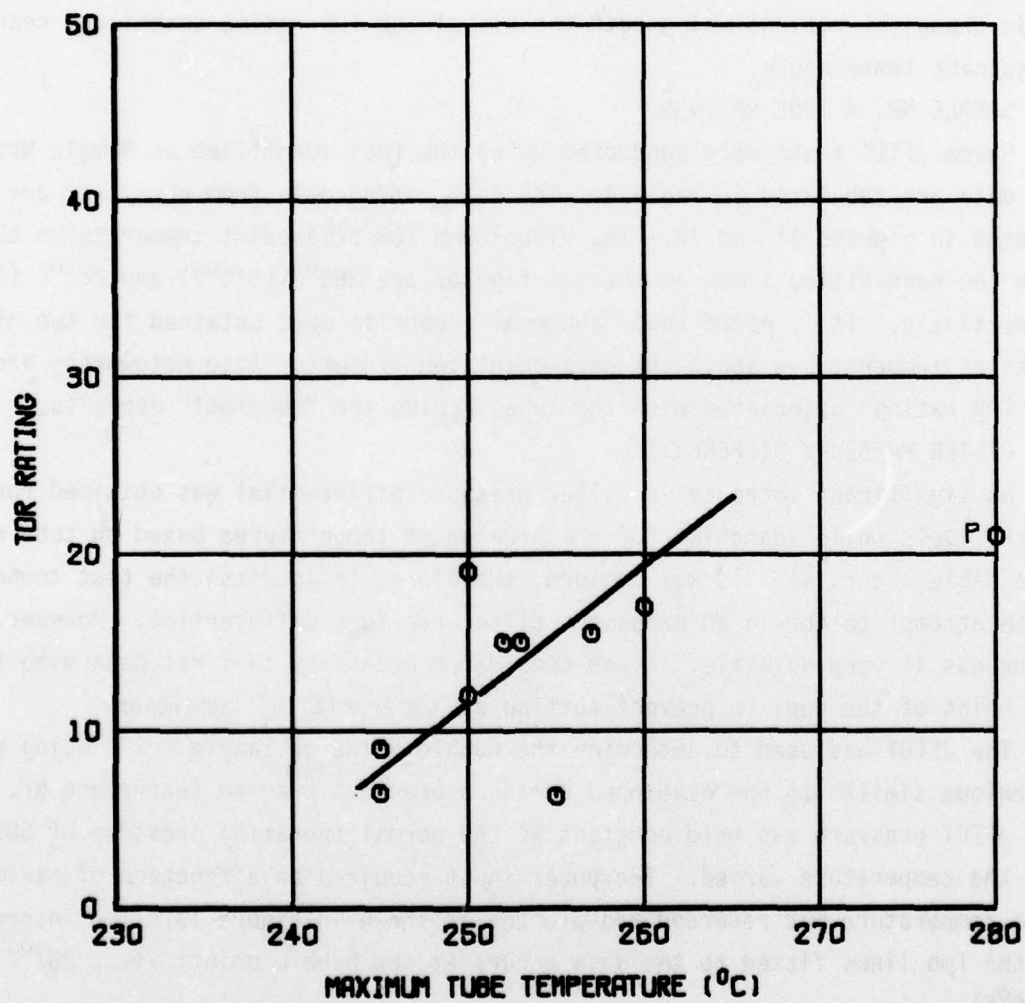


FIGURE 8. JFTOT RESULTS FOR SAMPLE NR. 2 - TOR RATINGS

3. SAMPLE NR. 3 TUBE RATINGS

A total of nine JFTOT tests were conducted on the motor gas identified as Sample Nr. 3. The data are tabulated in Table 3. The tube rating data from each test are plotted in Figures 9 and 10. The Visual and TDR breakpoint temperatures obtained from the lines shown in the two figures are 273°C (523°F) and 269°C (516°F), respectively.

The fuel sample produced peacock type deposits when failure occurred and the characteristic multi peaked TDR rating curve was evident when the TDR was used to rate the tubes. "Abnormal" deposits were reported for two of the tests. The data indicate that the fuel is a sharp or rapid breaking fuel; i.e., exhibits a rapid change in ratings using both the Visual and TDR rating techniques near the breakpoint temperature.

4. SAMPLE NR. 4 TUBE RATINGS

Seven JFTOT tests were conducted using the fuel identified as Sample Nr. 4. The data are tabulated in Table 4. The tube rating data from each test are plotted in Figures 11 and 12. The Visual and TDR breakpoint temperatures obtained from the hand-fitted lines in the two figures are 266°C (510°F) and 267°C (512°F), respectively. It is noted that "abnormal" deposits were obtained for two of the tests at temperatures above the breakpoint temperature. Also noteworthy are the low TDR ratings associated with the tubes having the "abnormal" deposits.

5. FILTER PRESSURE DIFFERENTIAL

No significant increase in filter pressure differential was obtained for any of the fuels while searching for the breakpoint temperatures based on tube ratings (see Table 1 thru 4). It was decided, therefore, to increase the test temperature in an attempt to obtain an excessive filter pressure differential. However, since motor gas is very volatile, it was considered necessary to first determine the bubble point of the fuel to prevent testing at supercritical conditions.

The JFTOT was used to determine the bubble point of Sample Nr. 2 using a technique similar to one developed during a previous program (Reference Nr. 4). The JFTOT pressure was held constant at the normal operating pressure of 500 psig and the temperature varied. The power input required as a function of maximum tube temperature was recorded and plotted as shown in Figure 13. The intersection of the two lines fitted to the data occurs at the bubble point; viz., 287°C (549°F).

ASTM Test Method D-2889 (Reference 1) provides a method for calculating the true vapor pressure of petroleum distillates using the ASTM D-86 distillation

TABLE 3. JFTOT RESULTS FOR FUEL SAMPLE NR. 3

<u>DATE TESTED</u>	<u>CONTROL TEMP (°C)</u>	<u>VISUAL RATING</u>	<u>TDR RATING</u>	<u>FILTER PRESS. DROP MM-HG (Minutes)</u>
23 Dec 76	250	1+	1.7	0 (150)
28 Dec 76	240	1A	-1.7	0 (150)
29 Dec 76	260	1	0.2	0 (150)
30 Dec 76	260	1+	5.4	0 (150)
30 Dec 76	230	1+	0.1	0 (150)
4 Jan 77	240	1	-1.1	0 (150)
7 Jan 77	280	4+AP	47.2	0 (150)
12 Jan 77	270	1	5.9	0 (150)
18 Nov 77	280	4+P	32.8	0 (150)

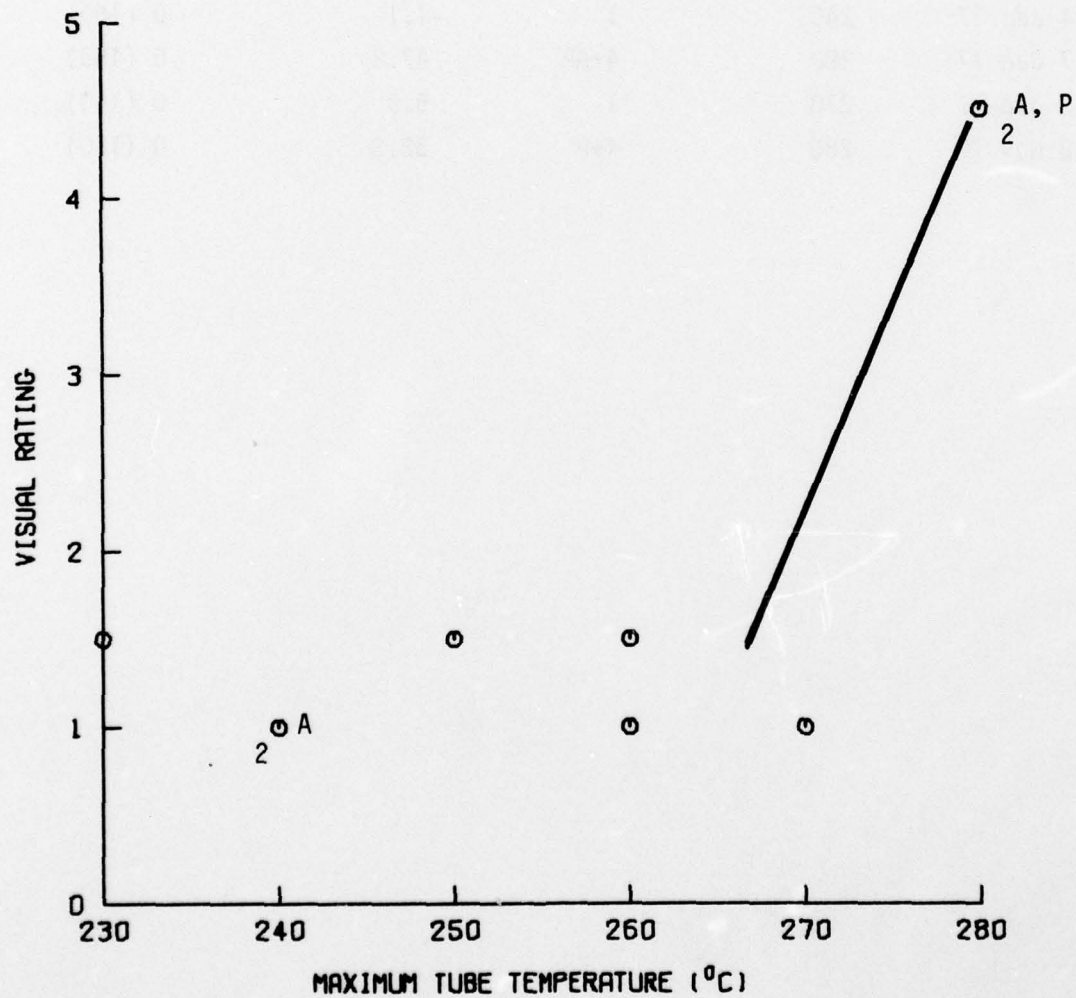


FIGURE 9. JFTOT RESULTS FOR SAMPLE NR. 3 - VISUAL RATINGS

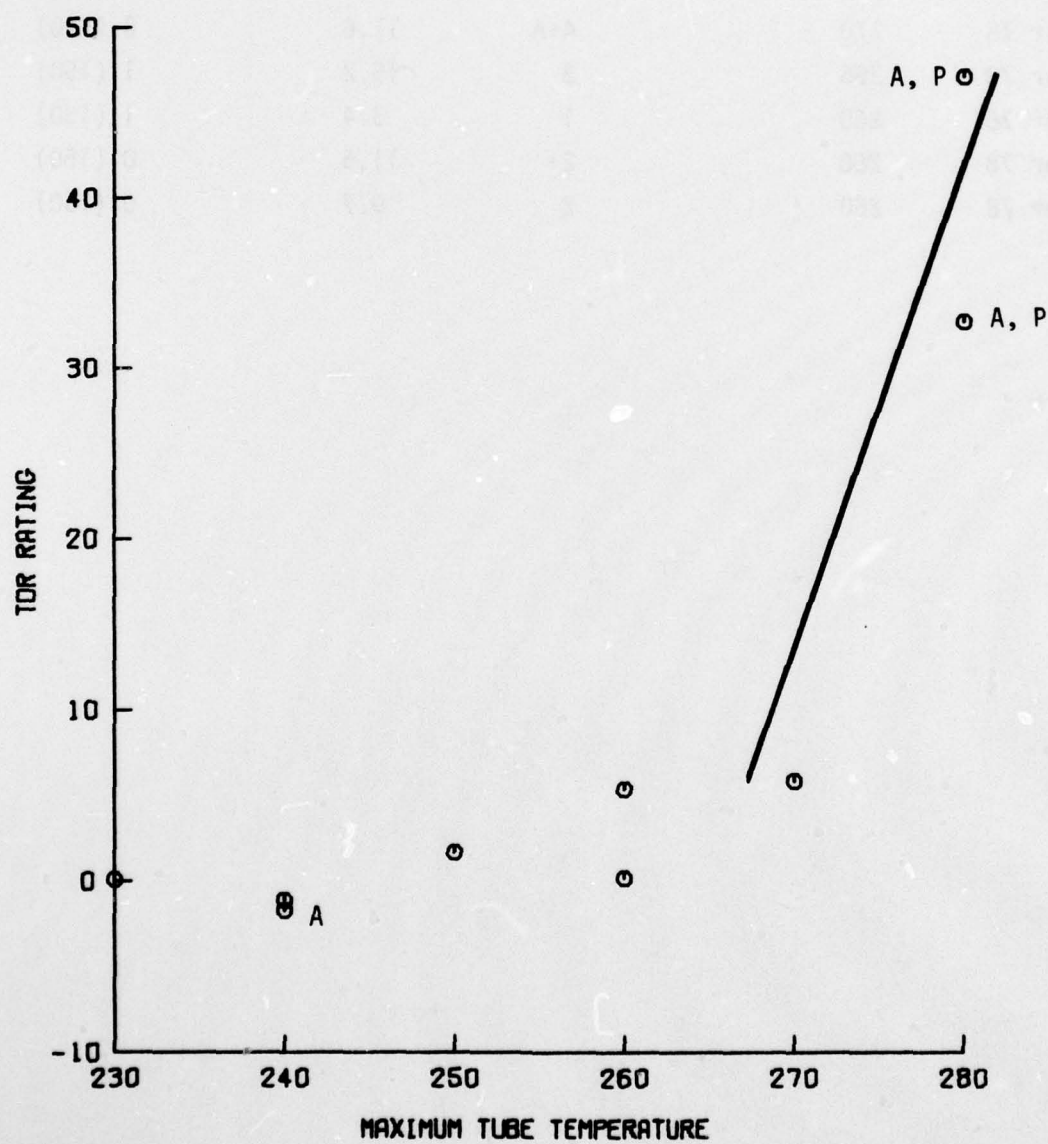


FIGURE 10. JFTOT RESULTS FOR SAMPLE NR. 3 - TOR RATINGS

TABLE 4. JFTOT RESULTS FOR FUEL SAMPLE NR. 4

<u>DATE TESTED</u>	<u>CONTROL TEMP (°C)</u>	<u>VISUAL RATING</u>	<u>TDR RATING</u>	<u>FILTER PRESS. DROP MM-HG (Minutes)</u>
27 Feb 78	270	3	8.8	0 (150)
28 Feb 78	275	4+A	14.9	0 (150)
10 Mar 78	270	4+A	11.6	0 (150)
13 Mar 78	265	3	15.2	1 (150)
14 Mar 78	260	1	3.4	1 (150)
16 Mar 78	260	2+	11.5	0 (150)
20 Mar 78	260	2	9.7	0 (150)

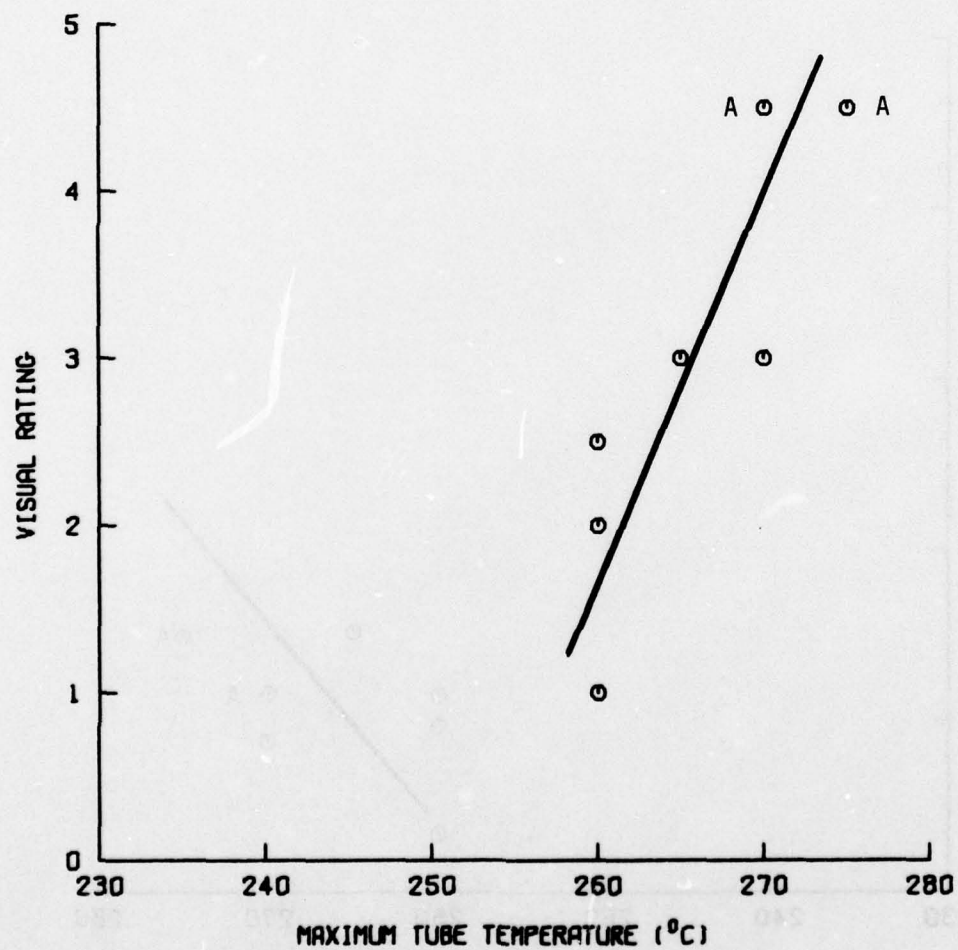


FIGURE 11. JFTOT RESULTS FOR SAMPLE NR. 4 - VISUAL RATINGS

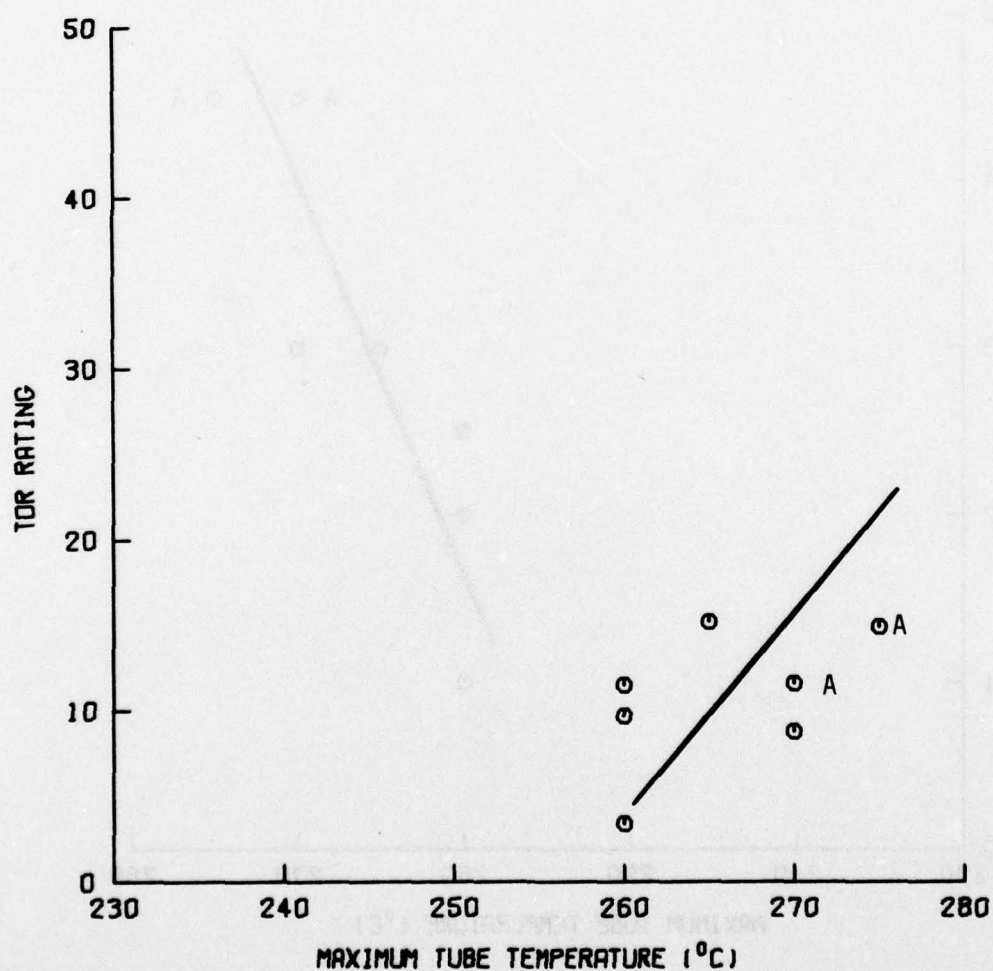


FIGURE 12. JFTOT RESULTS FOR SAMPLE NR. 4 - TDR RATINGS

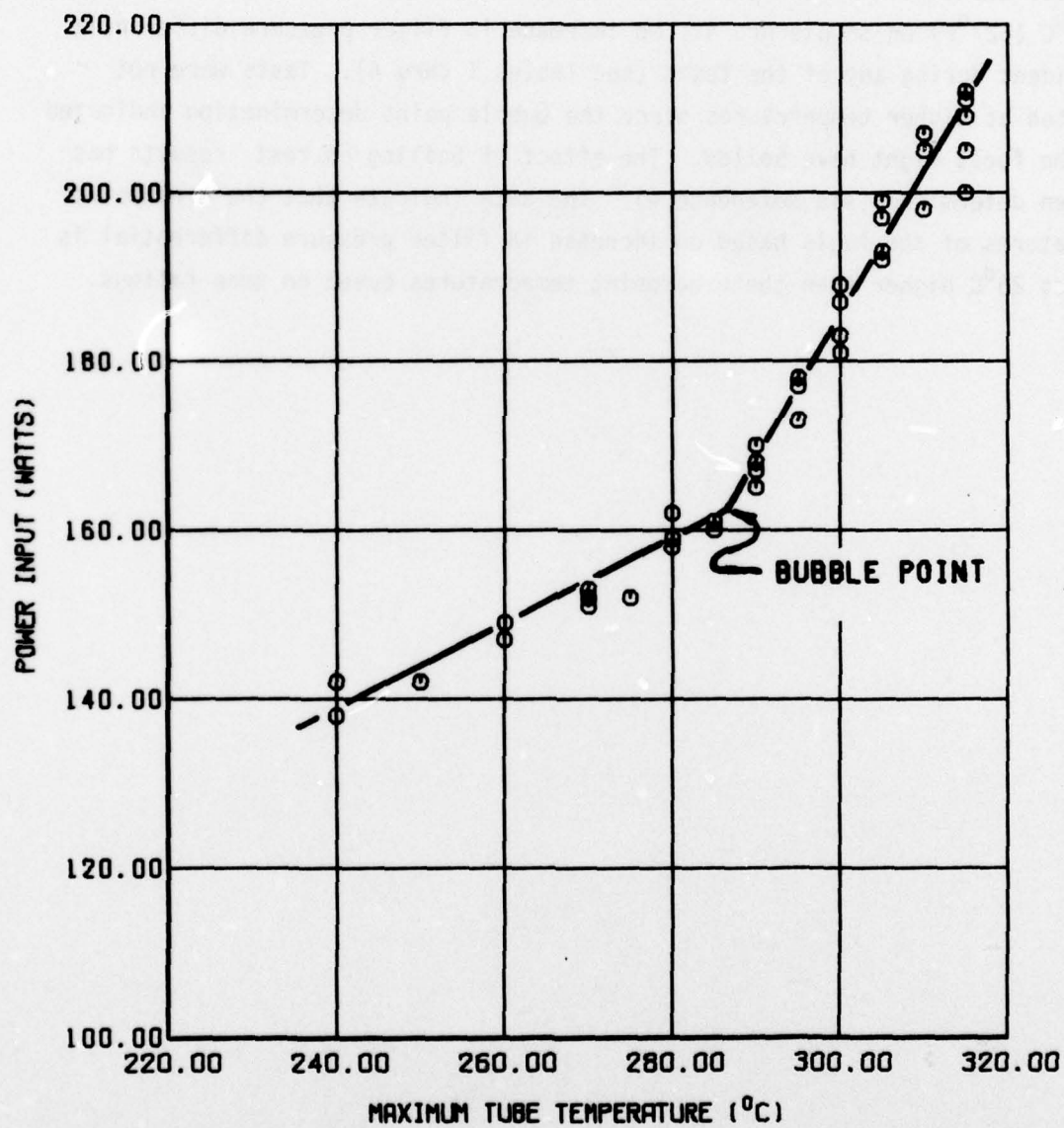
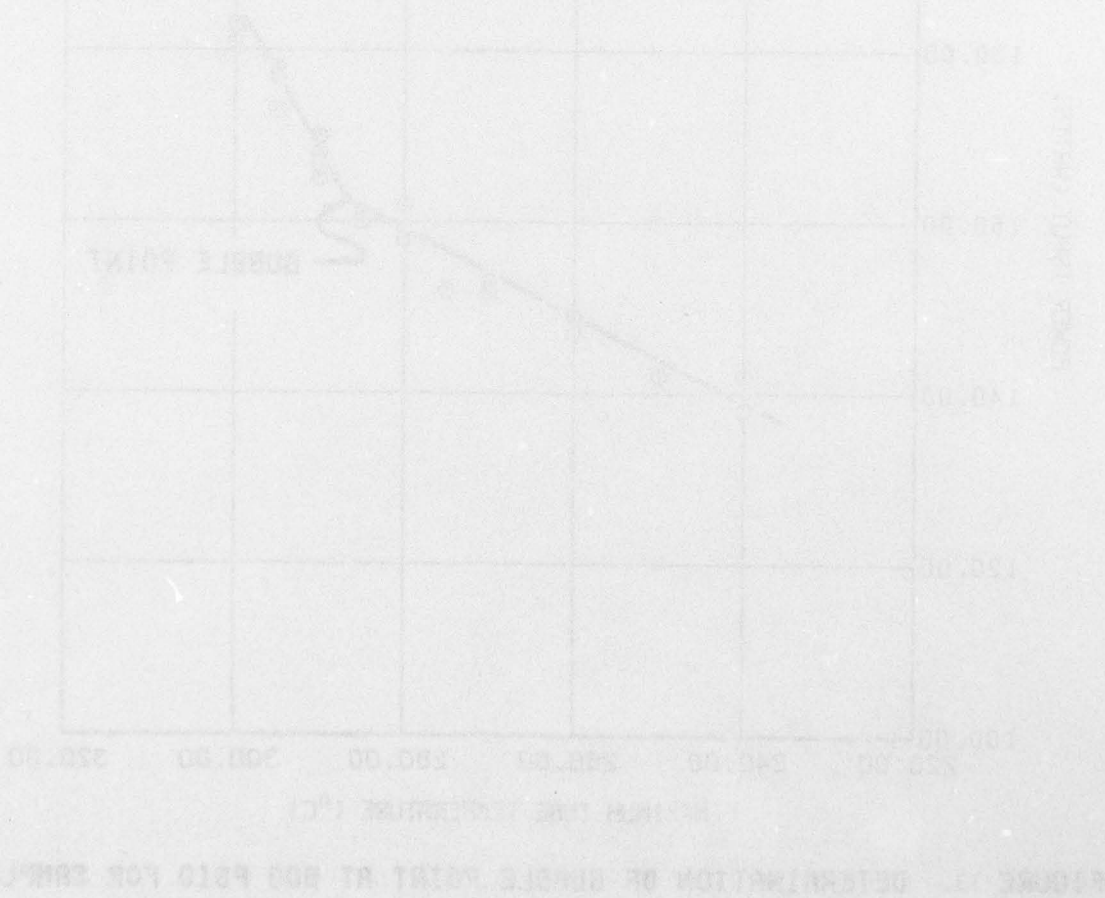


FIGURE 13. DETERMINATION OF BUBBLE POINT AT 500 PSIG FOR SAMPLE NR. 2

data and the gravity. This method was used to calculate the bubble point line for a typical motor gas. The resulting line is shown in Figure 14. The bubble point determined using the JFTOT is also shown in Figure 14. Reasonable agreement between the two techniques is evident when it is considered that the bubble point line was determined for a typical motor gas, not the motor gas in the JFTOT test.

JFTOT tests were conducted at 280°C (536°F) on Samples Nr. 1, 2, and 3 and at 275°C (527°F) on Sample Nr. 4. No increase in filter pressure differential was evident during any of the tests (see Tables 1 thru 4). Tests were not conducted at higher temperatures since the bubble point determination indicated that the fuels might have boiled. The effect of boiling on test results has not been determined (see Reference 4). The data indicate that the breakpoint temperatures of the fuels based on increase in filter pressure differential is at least 25°C higher than the breakpoint temperatures based on tube ratings.



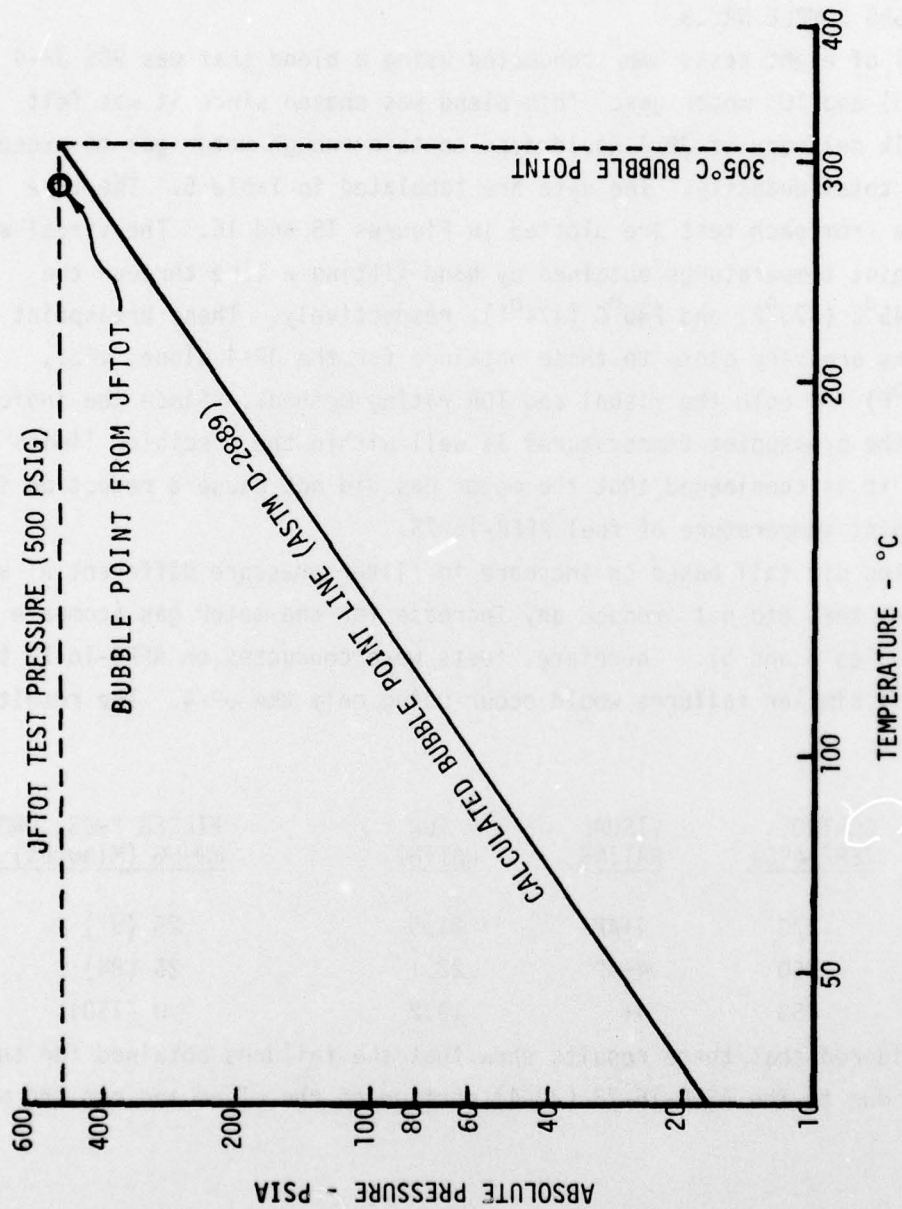


Figure 14. Bubble Point Line for Motor Gas

SECTION V

RESULTS USING MOTOR GAS BLENDED WITH JP-4

1. MOTOR GAS SAMPLE NR. 3

A total of eight tests was conducted using a blend that was 90% JP-4 (AFFB-16-73) and 10% motor gas. This blend was chosen since it was felt that no bulk delivery of JP-4 would ever contain enough motor gas to exceed 10% of the total quantity. The data are tabulated in Table 5. The tube rating data from each test are plotted in Figures 15 and 16. The Visual and TDR breakpoint temperatures obtained by hand-fitting a line through the data are 245°C (473°F) and 246°C (474°F), respectively. These breakpoint temperatures are very close to those obtained for the JP-4 alone; viz., 249°C (480°F) for both the Visual and TDR rating methods. Since the indicated change in the breakpoint temperatures is well within the precision limits of the JFTOT, it is considered that the motor gas did not cause a reduction in the breakpoint temperature of fuel AFFB-16-73.

The blend did fail based on increase in filter pressure differential at temperatures that did not produce any increase for the motor gas (compare data shown in Tables 3 and 5). Therefore, tests were conducted on AFFB-16-73 to determine if similar failures would occur using only the JP-4. The results obtained are:

<u>DATE TESTED</u>	<u>CONTROL TEMP (°C)</u>	<u>VISUAL RATING</u>	<u>TDR RATING</u>	<u>FILTER PRES. DROP MM-HG (Minutes)</u>
17 Jan 77	270	4+AP	21.5	25 (97)
21 Jan 77	260	4+AP	22.1	25 (84)
24 Jan 77	250	4+	19.2	0 (150)

It is considered that these results show that the failures obtained for the blend were due to the AFFB-16-73 (JP-4) portion of the blend and not the motor gas.

Motor gas sample Nr. 3 was blended with a JP-4 having a lower breakpoint temperature than the breakpoint temperature of the motor gas. In addition, the breakpoint temperature of the JP-4 was below the JP-4 specification limit. Thus, while it was possible to conclude that the motor gas did not degrade the

TABLE 5. JFTOT RESULTS FOR FUEL SAMPLE NR. 3 BLENDED
WITH AFFB-16-73

<u>DATE TESTED</u>	<u>CONTROL TEMP (°C)</u>	<u>VISUAL RATING</u>	<u>TDR RATING</u>	<u>FILTER PRESS. DROP MM-HG (Minutes)</u>
5 Jan 77	250	4+A	18.5	2 (150)
6 Jan 77	240	2+A	5.9	0 (150)
13 Jan 77	245	4+A	15.9	1 (150)
13 Jan 77	270	4+P	23.0	25 (15)
14 Jan 77	240	1+A	6.0	0 (150)
14 Jan 77	260	4+	16.5	25 (81)
25 Jan 77	250	3	15.0	1 (150)
1 Feb 77	247	2+A	15.9	0 (150)

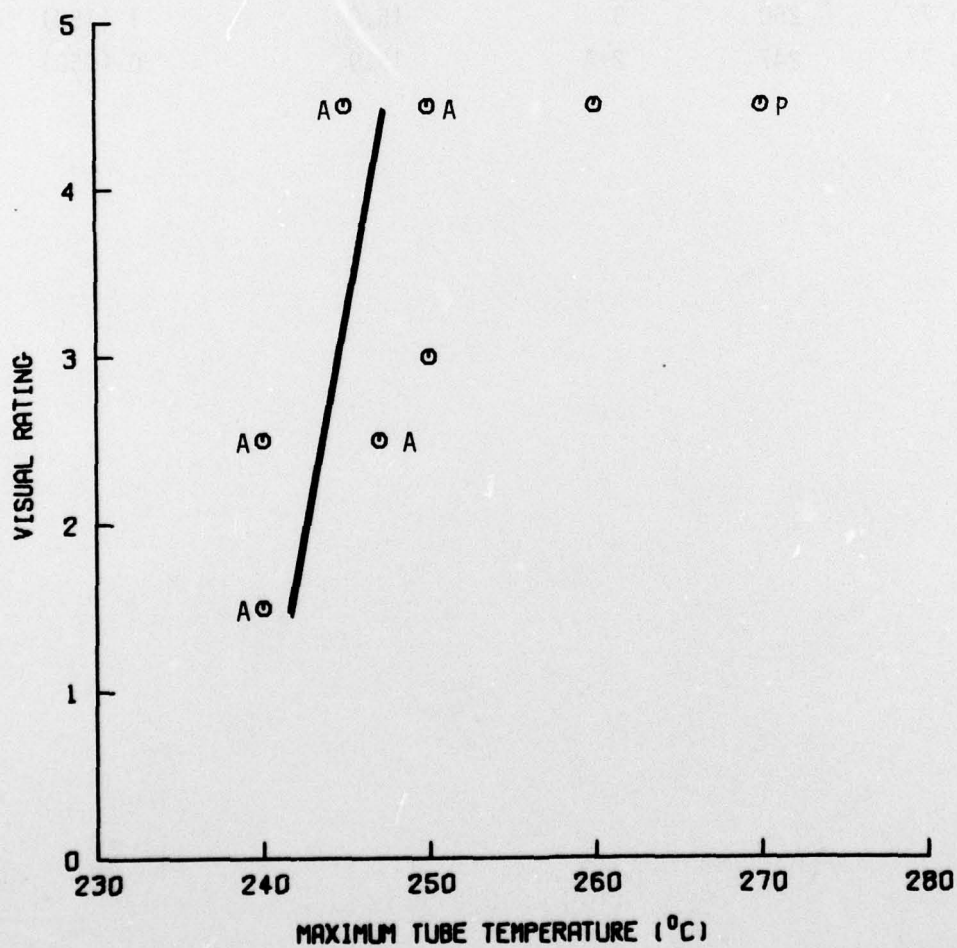


FIGURE 15. EFFECT OF SAMPLE NR. 3 ON JP-4 AFFB-16-73 (VISUAL RATINGS)

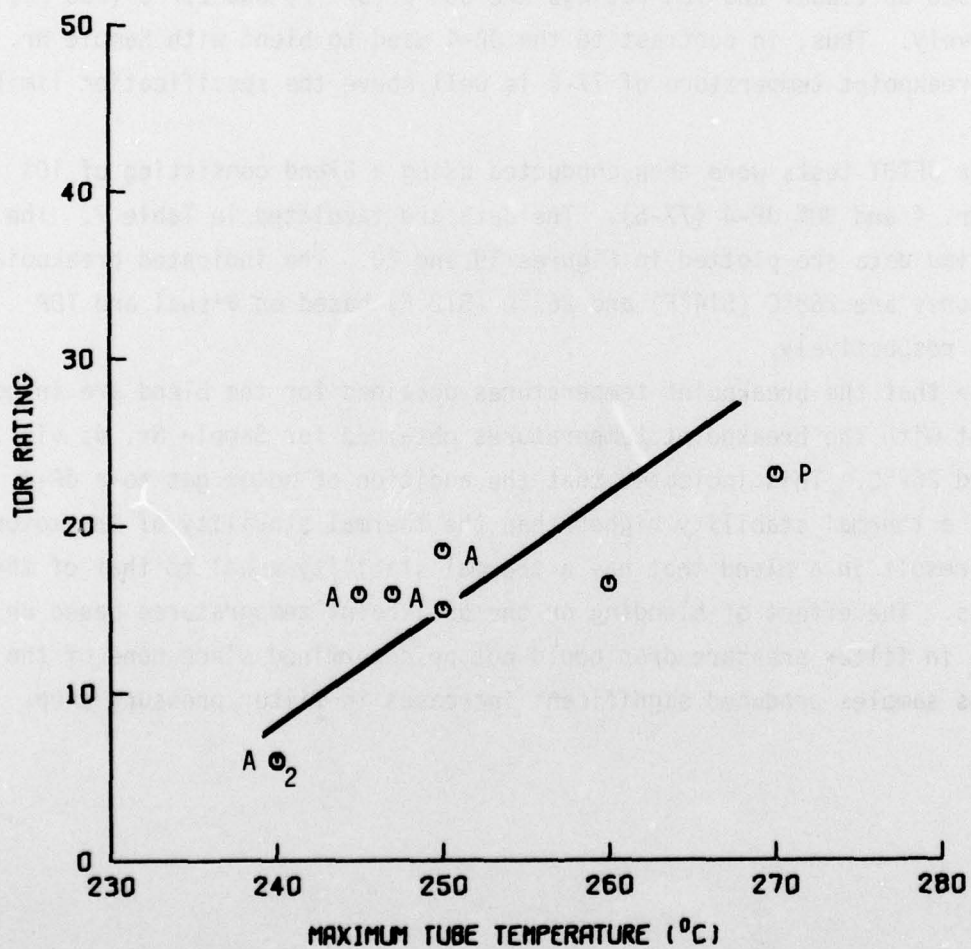


FIGURE 16. EFFECT OF SAMPLE NR. 3 ON JP-4 AFFB-16-73 (TOR RATINGS)

JP-4, it was not possible to conclude that (1) the motor gas would not degrade a JP-4 having a breakpoint temperature above that of the motor gas and (2) the resulting breakpoint temperature of the blend would be below the specification limit for JP-4.

2. MOTOR GAS SAMPLE NR. 4

The JP-4 chosen to blend with fuel Sample Nr. 4 was identified as 77-6. A series of five JFTOT tests were conducted using 77-6 and the results are presented in Table 6. The tube-rating data are plotted in Figures 17 and 18. Hand-fitted lines through the data indicate that the breakpoint temperatures based on Visual and TDR ratings are 300°C (571°F) and 297°C (566°F), respectively. Thus, in contrast to the JP-4 used to blend with Sample Nr. 3, the breakpoint temperature of 77-6 is well above the specification limit for JP-4.

Four JFTOT tests were then conducted using a blend consisting of 10% Sample Nr. 4 and 90% JP-4 (77-6). The data are tabulated in Table 7. The tube-rating data are plotted in Figures 19 and 20. The indicated breakpoint temperatures are 268°C (514°F) and 267°C (512°F) based on Visual and TDR ratings, respectively.

Note that the breakpoint temperatures obtained for the blend are in good agreement with the breakpoint temperatures obtained for Sample Nr. 4; viz., 266°C and 267°C. This indicates that the addition of motor gas to a JP-4 that has a thermal stability higher than the thermal stability of the motor gas may result in a blend that has a thermal stability equal to that of the motor gas. The effect of blending on the breakpoint temperatures based on increase in filter pressure drop could not be determined since none of the motor gas samples produced significant increases in filter pressure drop.

TABLE 6. JFTOT RESULTS FOR FUEL 77-6

<u>DATE TESTED</u>	<u>CONTROL TEMP (°C)</u>	<u>VISUAL RATING</u>	<u>TDR RATING</u>	<u>FILTER PRESS. DROP MM-HG (Minutes)</u>
27 Feb 78	270	1	1.7	1 (150)
28 Feb 78	290	1	2.4	2 (150)
28 Feb 78	310	4	19.2	0 (150)
1 Mar 78	290	1	6.8	0 (150)
7 Mar 78	300	4	20.3	1 (150)

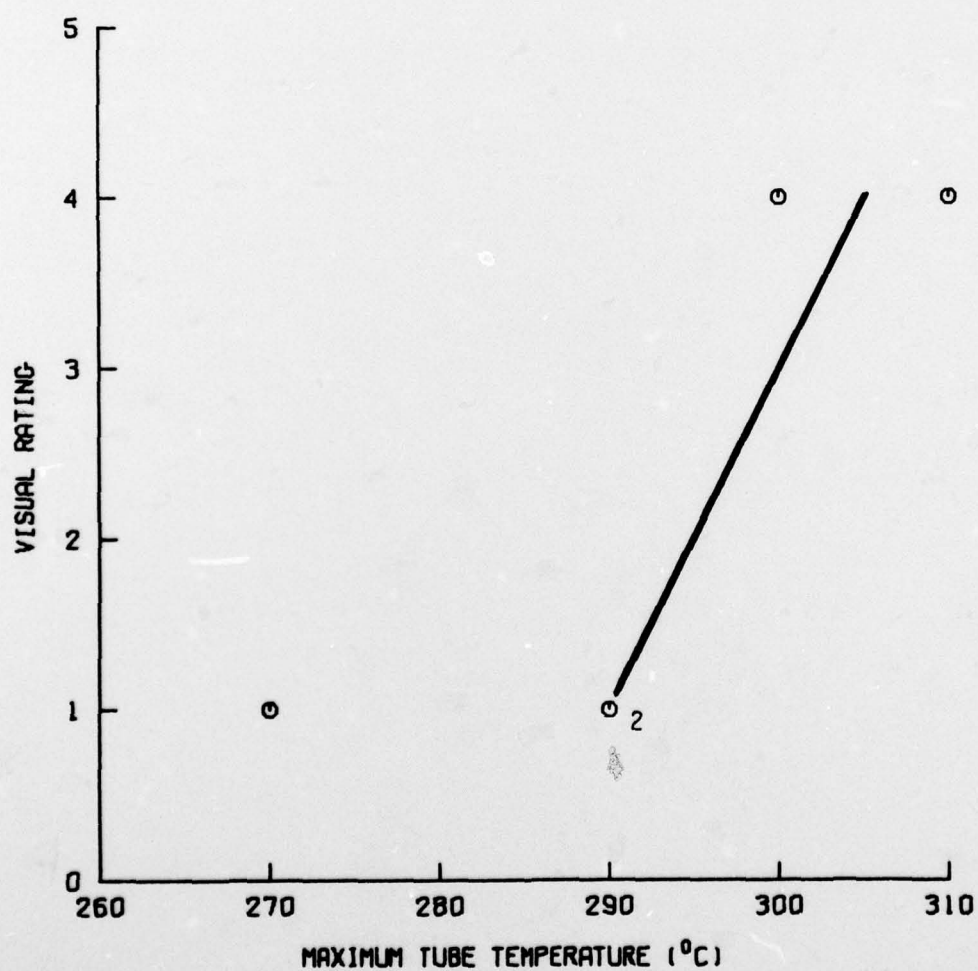


FIGURE 17. JFTOT RESULTS FOR JP-4 77-6 (VISUAL RATINGS)

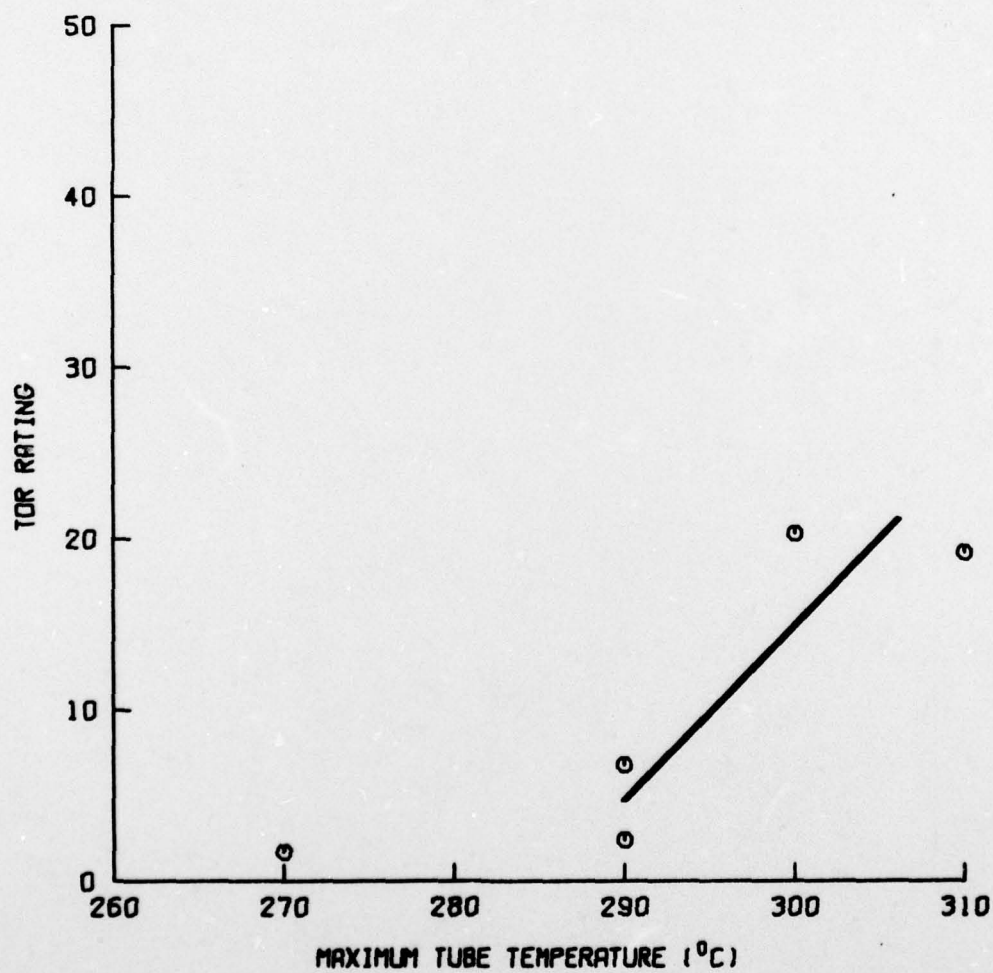


FIGURE 18. JFTOT RESULTS FOR JP-4 77-6 (TOR RATINGS)

TABLE 7. JFTOT RESULTS FOR FUEL SAMPLE NR. 4 BLENDED WITH 77-6

<u>DATE TESTED</u>	<u>CONTROL TEMP (°C)</u>	<u>VISUAL RATING</u>	<u>TDR RATING</u>	<u>FILTER PRESS. DROP MM-HG (Minutes)</u>
21 Mar 78	270	3	15.4	2 (150)
22 Mar 78	260	1	5.2	0 (150)
23 Mar 78	270	3+P	14.8	6 (150)
24 Mar 78	260	2	5.4	10 (150)

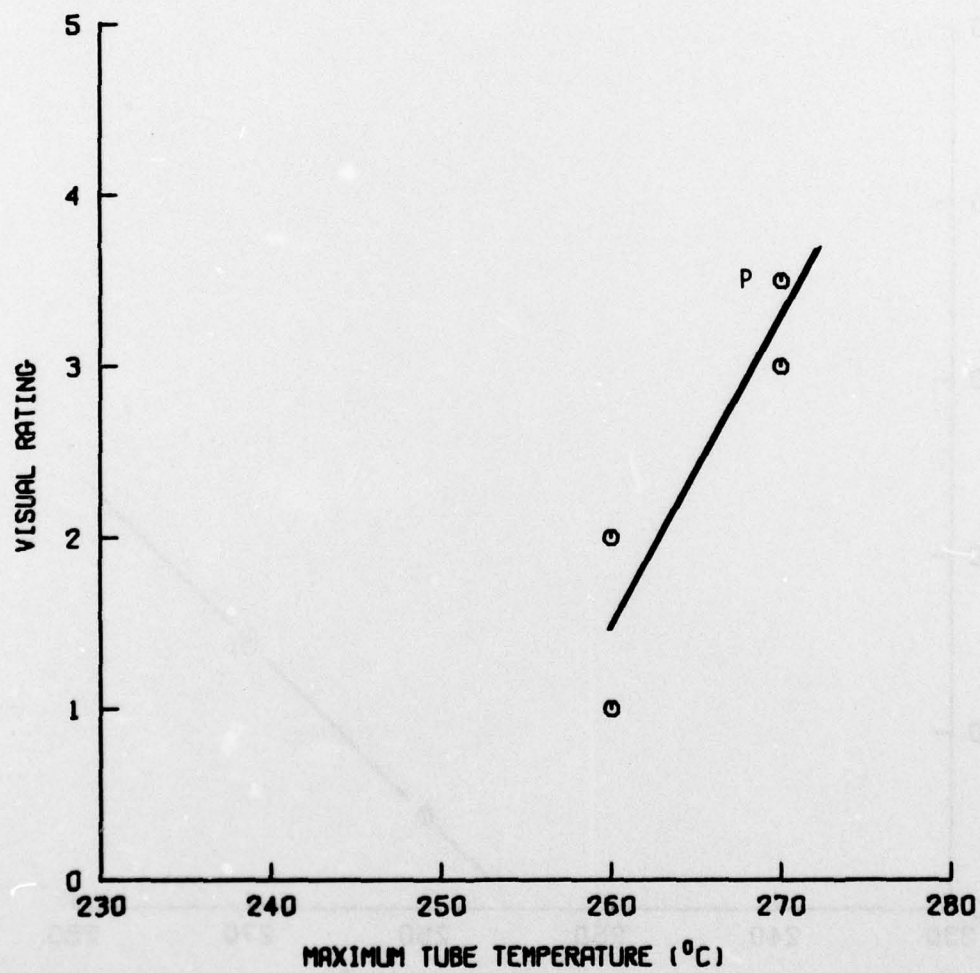


FIGURE 19. EFFECT OF SAMPLE NR. 4 ON JP-4 77-6 (VISUAL RATINGS)

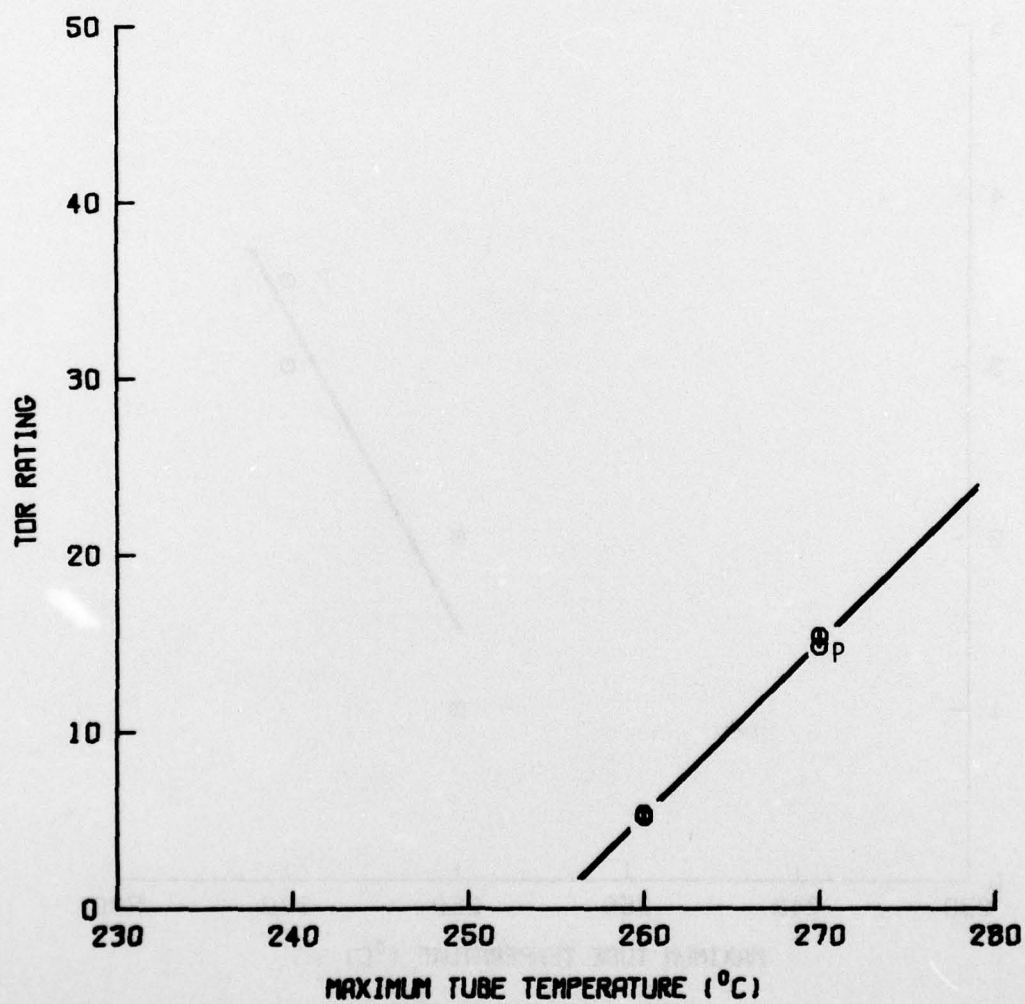


FIGURE 20. EFFECT OF SAMPLE NR. 4 ON JP-4 77-6 (VISUAL RATINGS)

SECTION VI
CONCLUSIONS

1. The breakpoint temperatures of the motor gas fuels tested were not over 10°C below the specification limit for JP-4. Thus, it is considered that these fuels would not cause thermal stability problems when used in an aircraft on an emergency basis.
2. Motor gas should not be used at or above temperatures approaching 287°C (549°F) since boiling may occur. The "worst case" distillation curve would have to be determined before a definite limit could be set and the operating pressure (500 psig for the JFTOT) would also have to be considered.
3. Adding motor gas to JP-4 may result in a lowering of the thermal stability of the blend to the level of the thermal stability of the component having the lower thermal stability.
4. The deposits formed on the JFTOT tubes produced visual and TDR rating responses similar to those produced by JP-4.
5. Peacock type deposits occur at temperatures above the breakpoint temperature of a fuel if they occur.
6. The limited data indicates that final TDR ratings are significantly affected by the initial ratings of the tubes.

SECTION VII RECOMMENDATIONS

1. Prior to a decision to use motor gas as an emergency jet turbine fuel, additional samples of motor gas should be evaluated. These samples should be obtained from sources representing the spectrum of crude types, processing, etc.
2. Before the TDR is used as a specification tool, further consideration should be given to the effect of initial tube ratings on the final results, especially if a low TDR rating is selected for the pass/fail criterion.

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